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Energy, environment and development in Cuba

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ABSTRACT

In Cuba, since 1959, the energy, environment and socio-economic development have been given high priority in national development plans.

Fifty years later, the Cuban people have achieved a society with notable advances in literacy and education, health, culture, sports, social security and per capita of the gross domestic product (GDP), which has permitted the attainment of a sustainable development, according to the World Wildlife Fund (WWF) report in 2006.

The energy sector has been evolving constantly in the last 50 years, achieving as the main result the distribution of electricity to 97% of the country, the growth of domestic oil production to achieve about 47% of the total consumption, the introduction of the distributed generation of electricity reaching 40% on the generation, rehabilitation of the electric appliances, systematization of the Cuban Electricity Conservation Program (PAEC), the Energy Conservation Program of the Ministry of Education (PAEME) and rapid introduction of renewable energy technologies, with good results in demand side management, energy efficiency and energy education.

Actually, soil degradation, deforestation, pollution, loss of biological diversity and lack of water have been identified as the main environmental problems; several plans and projects have been applied, in order to reduce their impact, following the policy expressed in the National Environmental Strategy.

However, challenges exist for future development in Cuba in coming years, from an economical point of view will be necessary the enhancement of the economic relations with the American and European countries, to solve internal problems such as insufficient productivity, correspondence between the level of activities with the financial, material and human resources, to promote growth in the levels of exports and to achieve the substitution of imported basic food; the energy sector need to achieve growth in the levels of prospection and exploitation of domestic oil, to diversify fossil energy and energetic technologies suppliers, energy efficiency and the use of renewable energy; the protection of the environment will demand to develop research about adaptation and mitigation of climate change, conservation and rational use of natural resources, in particular, the lands, water and forests.

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1. Introduction

Cuba is a developing country which emerged, half a century ago, from nearly 450 years of Spanish colonialism followed by 60 years of neocolonialism until the Cuban Revolution of January 1st, 1959.

The energy, the environment and socio economic development have been strategic objectives of the Cuban policy, in order to improve economic growth and quality of life of the population. In this regard, different economical and social plans have been implemented during the past five decades, achieving progress in the field of social developments in spheres such as health, education, culture, employment, sports and social security, among others. The Cuban economy has reached important growth in the production of food, electricity, nickel, petroleum, biotechnological and pharmaceutical products and tourism.

The implementation of the National Environmental Strategy, since 1997, has contributed significantly in bettering the main environmental problems of the past, in addressing present problems and in avoiding any further degradation of the environment.

The energy sector in Cuba has been undergoing a series of changes, which has permitted the distribution of electricity to 97% of the country, the introduction of the Cuban Electricity Conservation Program (PAEC) and the Energy Conservation Program of the Ministry of Education (PAEME), with good results in demand side management energy efficiency and energy education, and more recently in 2006, the Energy Revolution Programs which has changed the way the country transforms and uses the fuels technologies and sources of energy.

According to the Brundtland report, sustainable development is defined as a development that meets the present needs without compromising the ability of future generations to meet their own needs [1]. The progress of the one country toward sustainable development can be assessed using the Human Development Index (HDI) promoted by the United Nations Development Programs (UNDP), as an indicator of well being; values higher than 0.8 indicate a high level of human development; the ecological footprint is another indicator and represents a measure of demand on the biosphere; values lower than 1.8 ha per person, indicate the sustainability to world scale.

According to the World Wildlife Fund (WWF) report in 2006, Cuba reached a sustainable development because it shows a Human Development Index of 0.82 and 1.5 ha per people as a demand on the biosphere; this means that Cuba covers their present needs without compromising the ability of future generations to meet their own needs [2].

Unfortunately, the country have not reached a higher level of economical development due to external and internal factors; these include the persistency of the economic blockade during the last five decades with an economical affectation of around 1745.6 million dollars [3], the downfall on the Soviet Union Socialist Republics and socialist countries of Europe, and the catastrophic effects of the hurricanes that cross the country. Internal factors such as insufficient productivity, low correspondence between the level of activities with financial, material and human resources, insufficient energy conservation, promoting growth in the export levels and achieving the substitution imported basic food, have been recognized recently [4].

The main objective of this work is to present an update review of energy, environment and development approaches in Cuba. The first part of the paper starts with describing the geophysical setting of Cuba; this is followed by reviewing the social context with particular emphasis on health care and education systems. The second part, describes the main aspects of the economical development, future trends and planning. The third part has been dedicated to energy with its sources, the electrical power sector, the main benefits of the Energy Revolution and renewable energy. The final part, analyzes the main environmental problems identified in Cuba and action plans in order to prevent, reduce and control its consequences.

2. Background

2.1. Geophysical setting of Cuba

Cuba is a subtropical archipelago formed by the Island of Cuba (104,945 km^2), island of Youth (2200 km^2) and around 4195 keys and small islands. Geographically, the country, as shown in Fig. 1, is located in the Caribbean Sea, and lies between latitudes 20°12′–23°17′N and longitudes 80°53′–84°57′W. The country is bordered by the United States on the north; by the island of Jamaica on the south, Haiti on the east and the Yucatan Peninsula on the west.

Cuba is mainly a flat country, around 75% of the surface is formed by plains that alternate with three mountain regions located in the occident, the center region and in the east of the island; the highest peek is Pico Turquino with 1974 m above sea level.

Cuban climate is subtropical humid, with an annual average temperature of 25 °C in the summer and 20 °C in the winter. Average rainfall is 1059 mm in the rainy season (May–October) and 316 mm in the dry season (November–April). Annual relative humidity averages 78%. A significant element in the climate of Cuba is the hurricane that affects the country on an average of once every two years. The hurricanes or tropical hurricanes are areas of drops pressures of among 300–500 km of diameter that cause winds, rains and extremely strong sea surf that usually have catastrophic effects in the regions where they cross [5].

The very configuration of the island of Cuba is long and narrow which gives place to the existence of rivers of short course and reduced flow in their majority. The longest river is Cauto with a length of 370 km and the biggest is Toa River. The fluvial basins in a same way have relatively little extension and there are a total of 632 bigger than 5 km^2 with a fluvial glide of 31,682 million cubic meters [6].

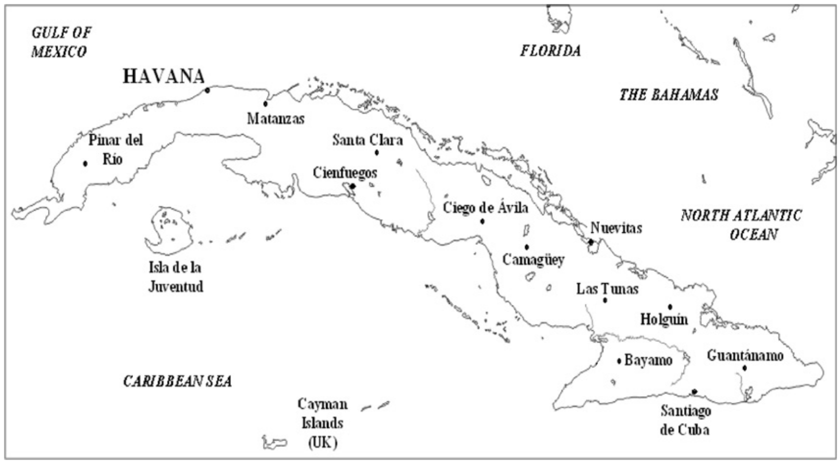


Fig. 1. Location of Republic of Cuba.

Source: Adapted from Hernandez (2001).

2.2. Social development in Cuba

Cuba is the most populated country in the Caribbean sea, with 11,242,628 people and the population growth rate was 0.3% in 2009, which was lower than the world average of 1.2% [7].

The urban population had increased to 75% and its rural counterpart to 25%, these demographic trends are the result of transformation processes currently taking place in the fields of education, health care, employment policy and the participation of women in the economic and social life of the country. Table 1 provides socio-economic indicators for Cuba.

The health care system in Cuba is regarded as a permanent priority and is available to all citizens without cost. The Cuban health care show, in 2009, an increase in life expectancy at birth to 77 years, the reduction of child mortality rate to 4.8 for every 1000 live births and a birth rate of 11.6 for every 1000 inhabitants [8]. In Cuba, there are, at present, 202 urban hospitals and 17 are rural hospitals; 498 polyclinics; 14 faculties for the medical sciences; 26 blood banks, where blood is tested and received without charge; and 233 homes for the elderly.

The Cuban education system is constantly being improved, guided by the principles of equity, universal and free access to all levels. At present, 2.9 million students are enrolled in Cuba accounting for over 26% of the population, the country had 7.5 graduated from the superior level for every 100 inhabitants, the students per teacher ratio has been reduced to 20, in the country 65 universities exist, 12,172 schools and more than 1100 day-care centres for children between 0 and 5 year old, and over 430 special schools which treat children with sensorial, intellectual and physical deficiencies. Two Educational Channels has been created on Cuban television. Its programming provides intellectual development up to university level, including different elements of universal culture; and materials covering almost all fields of human endeavour.

At present, 5,072,400 persons, male and female, are fully employed, equivalent to 74% of the population of working age; the unemployment rate currently stands at 1.7%. The women play an outstanding role in national development and enjoy equal opportunities both with respect to employment and remuneration levels.

The fields of social security and social assistance provide protection for more than one million persons.

Table 1
Socio-economic indicators of Cuba.

National name	República de Cuba
Capital of Cuba	La Habana
Total area (km^2)	110,860
Forest cover (%)	25.7
Arable land area (%)	33
Population (2009)	11,242,628
Urban population (%)	75
Population growth rate (%)	0.3
Total GDP (Cuban pesos) (2009)	46,352,000,000
Per capita GDP (Cuban pesos) (2009)	4124
Ethnicity/race (2002)	White 65%, mixed 24.9%, black 10.1%
Religions	Catholic and Santeria (Afro-Cuban syncretism)
Major industries	Services and medical products, tourism, mining
Major trading partners	Venezuela, China, Canada, Spain, Russia

Source: Adapted from Statistical Yearbook of Cuba [6].

2.3. Overview of the development trends and planning in Cuba

After the triumph of the Cuban Revolution in 1959, a number of measures conductive to the development were necessary which included: nationalization of agricultural holding, petroleum, telephones, mines, refineries and export–import concerns. In a quick succession of measures, the United State cut the Cuban sugar import quota and imposed a punitive embargo, that still effective today.

In early 1960, Cuba suffered an enormous economic shock and with great difficulty, reoriented its production and trade to the possibilities and demands of the Soviet bloc and a substantial economic development took place.

In February 1960, Cuba negotiated a sugar-for-oil exchange with the Soviet Union that began the extraordinary transformation of Cuba and two years later, the nation began conducting 85% of its foreign trade with the Soviet bloc.

Despite external and internal pressures, the government formulated the 1st Four-Year Plan (1962–1965) of economic development, in order to transform Cuba from agrarian in an agro industrial country, due to the historical experience in the sugar cane production. In 1963 it was not possible to fulfill the plan, due to lack of financial support, equipment, spare parts and workforces such as economics and technicians.

The 2nd Five Year Plan (1965–1970) set the following goals: improving quality of life and income, rapid exports growth, access to public service such as education, healthcare and social security. In order to achieve these objectives, the strategic government priorities included the production of 10 million tonnes of sugar cane. In

1970, due to lack of industrial infrastructure, workforces and inadequate methods of economic management, it was only possible to reach 8.5 million tonnes of sugar cane, productivity.

In 1970, the rectification of economic politics began, in order to eliminate idealism mistakes in the previous plan.

In Cuba, between 1970 and 1975 an increase was observed in production levels of electricity, lubricant, steel, nickel, paper, clothing, shoes, fertilizers, herbicides, cement, fish, food pastes, ice cream. During this period, more than 17,000 km of road were building and the construction level achieved an increase of 25% per annum.

The 4th Five Year Plan (1976–1980) approved by the government in December 1975, set the following goals: to achieve industrial growth in the production of sugar cane, nickel, chemicals, food, textiles; to expand the economic infrastructure and a short term credit system for all enterprises.

During this period the investment process was raised to 75% higher than the previous plans, the industry received 35% and the agriculture 19%, respectively. In 1980 it was announced that the actual growth rate was 4%.

The 1981–1985 plan introduced new incentive schemes and gave more freedom to market forces; it also eased restrictive hiring regulation. One of the major aims of the plan was to increase the industry's share of gross social product to 50%, but the industry accounted for only 45.3% in 1985. The 1986–1990 plan envisioned a 5% annual growth and aimed particularly at an increase in exports [9].

In Cuba, between 1989 and 1993, the gross domestic product (GDP) declined by 35%, as result of the disintegration of the Soviet Union, the collapse of Eastern European bloc, and the Council for Mutual Economic Assistance. The markets for their exports and the hard currency for imports disappeared. The supplies of spare parts, fuel, medicine, agricultural and chemicals, all diminished drastically, Cuba lost around 80% of its trading partners; this crisis was referred to as the Special Period in Peacetime, and the Cuban government implemented a continuing series of economic reforms including: the redirection of its trade towards the world market, major development of tourism, authorizing self-employment for some 250 occupations, allowing foreign investment in unexploited areas such as petroleum and mineral, specially nickel extraction and refining, telecommunications and agriculture derivatives such as alcoholic beverages, and citrus.

Under several finance and investment accords signed by Cuba and Russia in 1992 and 1993, Russia agreed to supply fuel, tires and spare parts for mechanical harvesters and other vehicles, fertilizers, and herbicides for Cuba's sugar harvest. In addition, Russia agreed to import a minimum of 2.0 million tonnes of Cuban sugar. Russia also agreed to extend a 350.0 million dollars credit to Cuba to complete and further develop a number of oil, energy and nickel mining projects that had previously been backed by the Soviet Union.

These measures resulted in modest economic growth; the drop in GDP halted in 1994, when Cuba reported 0.7% growth, followed by increases of 2.5% in 1995 and 7.8% in 1996.

Growth slowed again in 1997 and 1998 to 2.5% and 1.2%, respectively, as result of the failure to notice that sugar production had become uneconomic. The economic growth had picked up from 1999 with 9.2% to 2005 with 11.8%, respectively; it was the result of continued tourism growth since 2004, the volume of tourists has remained relatively consistent at 2.1 million and generates about 2000.0 million dollars annually; the mutually convenient, preferential agreement with Venezuela, China, Russia and other countries; and an upward trend in prices for key Cuban exports like nickel, sugar and biotechnology products.

In November 2004, a number of commercial accords were signed between Cuba and China in order to invest approximately 500.0 million dollars in a nickel operation in the municipal of Moa, Cuba would own 51% of the enterprise and Chinese-owned Minmetals the remaining 49%.

On April 28, 2005, Cuba and Venezuela signed 49 economic agreements, covering areas as diverse as oil (e.g. Venezuela sends around 90,000 barrels per day of crude oil and derivatives as diesel, gasoline, jet fuel), nickel, agriculture, shoes, textiles, tires, construction materials, electricity, transportation, health and education.

In October, 2006, Cuba and Russia signed accords in order to expand trade and investment. The new credit line is for 355.0 million dollars repayable over 10 years and it must be used to purchase Russian cars, trucks and planes, energy and transport infrastructure projects.

In December 2007, the National Assembly announced a growth of the GDP of 7.5%, which was below the 10% projected, because of the decline in the construction work and agricultural production due to climatic changes throughout the year, but was higher in comparison with the Latin America average of 5.6% [10]. During these years the investment process was 16.8%; agricultural production 24.7%; industry 7.8%, transport 7.9% with 1548 buses from China and Russia; nickel 2.2%; the pharmaceuticals industry expanded their production in 21%; and 11.7% social services.

Taking into account the trends of development during the previous plans and the international context, the Ministry of Economy considered it necessary to take a series of measures in order to get a solution for the Cuban economic problems, these include: to promote correspondence among the level of activities with the financial, material and human resources; to achieve growth in the investment for electricity generation, waterways and hydraulic installations, food production, transport and basic social services and hopes to reach an increase in the agriculture, industrial and services production; to make planning and economic administration more efficient; to raise export growth levels; to achieve substituting imported food like rice, beans, milk, fruit and wheat flour, as well as animal feed, with domestic production; to upgrade public transportation systems and infrastructure [11].

3. Overview of the energy situation

3.1. Fossil energy

In Cuba different energy plans have been implemented during the past 50 years, divided in three periods, the first beginning in 1959 and ending with the fall of the Soviet Union in 1991, the period included the country's largest build in energy generation infrastructure and highest rates of growth in consumption, based on oil and products imported from the Soviet Union highly subsidized. During the second period between 1992 and 2003 a National Energy Sources Development Program was implemented to reduce Cuban's energy imports and obtain maximum benefits from domestic energy sources [12]; in this period it was observed that a growth in domestic oil production achieved an increase of 7% per annum, the use of fuel oil in seven oil fired power stations which permitted a level of the electricity generation of around 15,000 GWh per year; unfortunately the domestic oil's high sulphur levels damaged the generation infrastructure severely. The period 2004 to present has been marked by the blackouts and energy crisis 2004–2005 and the Energy Revolution in 2006 which has changed the way the country transforms and uses the fuels technologies and sources of energy [13].

While the sector is now significantly more stable than the energy crisis, the high dependence on imported energy results in extremely high costs and the financial support of the Cuban's energy sector depend heavily from the Bolivarian Alternative for the Americas (ALBA), if this support is reduced or ended the country would fall in a new energy crisis [14].

Table 2
Fossil energy resources in Cuba 2009.

Energy source	Value	%
National		
Petroleum, million tonnes	2.731	34.0
Natural gas, million tonnes	1.019[a]	12.7
Imports		
Petroleum, million tonnes	3.150	39.2
Petroleum products, million tonnes	1.114	13.8
Mineral coal, thousand tonnes	15.6	0.2
Coke coal, thousand tonnes	8.7	0.1
Total, million tonnes	8.038	100

Source: Adapted from Statistical Yearbook of Cuba [6].
[a] Equivalent to 1.155 million m^3 of natural gas.

3.2. Energy resources

The largest source of domestic fossil energy, as shown in Table 2, comes from petroleum with 2.731 million tonnes oil (34.0%) in 2009, followed by natural gas with 1155 million of m^3 or 1.019 million tonnes oil (12.7%).

The import of fossil fuels, in 2009, included: 3.150 million tonnes of petroleum (39.2%); 1.114 million tonnes of petroleum products such as fuel oil, diesel, kerosene, liquefied propane gas, gasoline aviation, turbine fuel, lubricants (13.8%), 15.6 thousand tonnes of mineral coal (0.2%) and 8.7 thousand tonnes of coke coal (0.1%).

The national petroleum extraction (crude oil and gas) has grown in the last years from 0.700 million tonnes in 1990 to 3.750 million tonnes in 2009, it represent an increase of 5.3 times. The main oil field has been active in the Varadero zone, for nearly 50 years, and is beginning to dry up [6].

Recently, an offshore oil field has been discovered in the Gulf of Mexico, surrounding North West Cuba with an area higher than 30,000 km^2, the reserves are estimated in 20,000 million barrels of oil [15].

3.3. Energy generation, distribution and consumption

Before 1959, the Cuban electric power industry was controlled by foreign capital and limited to big cities and tourism resorts raising only an electrified level of 56% and an electricity production of 2550.4 GWh in 1958, as result of these situation large parts of the country were without electricity [16]. After of independence in 1959, the annual generation was raised until to reach 17,709.0 GWh in 2009, in correspondence with economic growth of the nation.

The structure of the power generation, as can be seen in Table 3, is formed by 9 Oil-Fired Power Stations with 60.8%, followed by 416 Fuel Oil Generators with 17.6% and 2 modern Gas-Fired Power Plants with 13.4%. Other important sources of power generation are 893 Diesel Generator, and around 54 Sugarcane Bagasse Fired Power Plants with 6.3% and 2.9%, respectively, in lesser proportions the electricity from the nickel industry with 1.8%, hydroelectric with 0.85%, old diesel generators with 0.84% and 3 wind parks with only 0.02%. The country also has a reserve of around 6000 diesel generators with 1320 MW, installed in key centres of the economy and services such as hospitals, clinics, food production centres, bakeries and schools, among others.

The Cuban government is planning to generate the 62.0% of the electricity with Fuel Oil Generators that will work 24 h per day, 25.0% with Gas-Fired Power Plants, 11.0% with Oil-Fired Power Plant and around 2.0% with Diesel generators, which will be operating during peak hours [17].

At present, the main generating, transmission and distribution facilities required for public supply, in Cuba, is the Electric Union (UNE), which is subordinate to the Ministry of Basic Industries (MINBAS).

The national transmission and distribution network reaches 97% of the country, with the exception of areas that are difficult to access due to the irregular topography, offshore islands and zones surrounding some sugar refineries where separate grids are operating in some cases.

In Cuba, in the last decade the energy consumption has remained steadily in correspondence with the growth of the gross domestic product which presented an average of 5.5% [11]. The total primary energy consumption was 7.315 million tonnes oil equivalent (toe), in 2009, of which 5.158 million toe come from crude petroleum (33.75%), followed by biomass (sugar cane bagasse and fuelwood) with 1.125 million toe (7.36%), natural gas with 1.019 million toe (6.66%) and in lesser proportions anthracite and bituminous coals with 13.36 thousand toe (0.09%).

On the other hand, the total consumption of secondary fuel sources was 7.967 million toe of which 7.815 million toe come from petroleum products (51.13%), manufactured gas with 87,660 toe (0.6%), charcoal with 55,550 toe (0.38%) and denaturalized alcohol with 9741 toe (0.06%).

Another important energy indicator, in a country, is the consumption of crude petroleum (crude oil and gas) and their products by sector. In Cuba, as shown in Table 4, the main consumers are agglutinated in the electricity production with 55.5%, followed by the mining exploitation with 16.3%, the industry with 10.2%, transport with 6.1% and in lesser quantities construction 3.0% domestic 3.0%, commerce 2.3%, agriculture 2.2% and miscellaneous consumers 1.4%.

The main power consumers in Cuba, as shown in Table 5, are concentrate in the domestic sector with 36.3%, followed by the industry with 25.4% and in lesser proportions, commerce, agriculture, transport, and construction with around 5.3%, and miscellaneous consumers 18.7%. The power losses represent a 14.3% of the total electricity generated; the Electric Union hope to decrease

Table 3
Structure of the gross power generation in Cuba 2009.

Type of generator	Units	Power (MW)	Production (GWh)	Production (%)
Oil-Fired Power Station	9	2273.0	10,772.2	60.82
Gas-Fired Power Station	2	495	2380.7	13.44
Fuel Oil Generators	416	904.2	3122.1	17.63
Diesel Generators	893	1219.8	1130.0	6.38
Old Diesel Generators	5	98.6	149.7	0.84
Nickel Industry Generator	3	214.1	333.0	1.88
Renewable energy				
Bagasse-Fired Power Plant	54	332.4	516.9	2.92
Hydroelectric	180	58	150.8	0.85
Wind Parks	3	7.2	3.5	0.02
Total		5602.3	17,709.1	100

Source: Adapted from Statistical Yearbook of Cuba [6].

Table 4
Structure of petroleum consumption in Cuba 2009.

Sector	Consumption (thousand tonnes)	Consumption (%)
Electricity production	3745.7	55.5
Mining exploitation	1103.9	16.3
Industry	690.8	10.2
Transport	414.1	6.1
Construction	205.4	3.0
Domestic	204.7	3.0
Commerce	156.7	2.3
Agriculture	149.4	2.2
Other sectors	82.6	1.4
Total	6753.3	100

Source: Adapted from Statistical Yearbook of Cuba [6].

Table 5
Structure of the power consumption in Cuba 2009.

Sector	Consumption (GWh)	Consumption (%)
Domestic	6425.8	36.3
Industry	4506.9	25.4
Commerce	254.5	1.4
Agriculture	316.6	1.8
Transport	264.0	1.6
Construction	82.1	0.5
Other sectors	3326.3	18.7
Losses	2532.9	14.3
Total	17,709.1	100

Source: Adapted from Statistical Yearbook of Cuba [6].

until 11% [18]. The per capita electricity consumption in Cuba, during 2009 raised a value of 1575.6 kWh.

3.4. The Energy Revolution in Cuba

In March 2005, seven inefficient big Oil-Fired Power Plants with 25 years average of work and higher specific consumption rates of 300 g/kWh, began to present frequent blackout in peak hours of maximum demand as a consequence of lack of maintenance, the poor quality of the domestic fuel oil, highly corrosive and a bad state of the electric grid; this situation worsened with the impact of two hurricanes that caused huge damage to the transmission and distribution power line. It affected important economic sectors and resulted in an energy crisis [19].

On January 17 of 2006, the Cuban government formulated a new energy initiative called the Energy Revolution, the main goals included: rehabilitation of the national electric grid; the generalization of distributed generation with smaller electric power plants, supplanting large old power plants; the substitution of inefficient appliances with energy saving bulbs, fans, electric pressure cookers, electric rice cookers, water pumps and refrigerators, to increase the exploration, production and use of local oil and natural gas in combined cycle gas-fired power stations, modernization of the auto motor park and rapid introduction of renewable energy technologies [18].

At present, the main results have been: the generalization of distributed generation by territories, in key centres with around 6000 small diesel generators (1320 MW) and 416 Fuel Oil Generators (904.2 MW), 893 diesel generators (1219.8 MW) with lower specific consumption rates (234 g/kWh), respectively; the substitution of around 9.4 million incandescent bulbs for energy saving lamps; more than 1.33 million fans has been distributed, 5.5 million electric pressure cookers, 3.4 million electric rice cookers, 0.2 million electric water pumps, 2.04 million domestic refrigerators and 0.1 million televisions. Until 2009, around 90% of the national electric grid has been rehabilitated [20].

In the future, the main challenge of the Energy Revolution will be to achieve the energy sustainable development, taking in consideration the condition of developing the country, the persistency of the economic blockade, the poor quality of the domestic fuel oil and the catastrophic effects of the hurricanes that cross the country.

3.5. Renewable energy

In the last five decades, a lot of activities in the field of renewable energy have been done and needed to be encouraged and continued, and have played an important role in the economical and social development in Cuba.

At present, renewable energy in exploitation is around 2,042,000 tonnes of oil equivalent (toe), which is around 54.5% of Cuban annual crude oil production in 2009, and a total installed capacity of 400 MW, contributing about 4.0% of the national electricity generation.

The main energy sources are concentrated in biomass with 2,027,530 toe (99.3%), followed by hydroelectric energy with 12,970 toe (0.6%), and in lesser proportions solar energy with 1165 toe (0.06%) and wind energy 640 toe (0.04%).

Cuba developed an ambitious photovoltaic electrification program to bring electricity to the rural population, around 6068 modules have been electrified with a total installed capacity of around 1.8 MW, the beneficiaries have been households, schools, medical clinics and cultural houses [21].

The solar water heating has been widely used in the last 30 years, presently Cuba spends between 4.5 and 7% of the national generation of electricity in heating water, so, in order to decrease this consumption around 8000 solar water heaters are working in several institutions including hospital, hotels and schools, with a total installed capacity of 3.9 MW, and an annual saving of 935 toe [22].

Today, three wind power plants were installed in Cuba, with a total capacity of 7.2 MW with an average electrical energy production of 3.0 GWh per year, allowed to salve around 300 toe per year [20], the Cuban government is planning to reach a goal of 500 MW. Wind energy for water pumping is very common in rural zones, with more than 4850 windmills installed; the Ministry of Sugar has announced the future installation of 4000 new windmills.

The main energy potential from biomass is concentrated in the sugar cane bagasse with 1,194,530 toe (48.20%), followed by fuelwood with 776,945 toe (31.30%), biogas 251,784 toe (10.15), sugar cane straw 164,800 toe (6.70%), charcoal 55,550 toe (2.25%), rice husk 33,040 toe (1.30%), sawdust 1680 toe (0.06%) and coffee husk 1120 toe (0.04%).

Nowadays, not all biomass generated can be used, only as energy sources sugar cane bagasse (58.90%), fuelwood (38.30%), charcoal (2.78%) and biogas (0.02%), with a total of 2,027,520 toe, which is about 81.7% of the total available biomass in Cuba.

In Cuba presently, 180 hydroelectric power plants have been constructed, reaching a total installed capacity of 58 MW in 2009, with an average electrical energy production of 150.8 GWh per year, representing an annual saving of 12,970 toe.

The potential is distributed between 9960 household mainly in rural zones, which it around 0.3% of the total households in Cuba, and benefited by about 34,900 people, 138 schools, 78 communities, clinics and others in an economical and social way. Cuba hopes in 2020, to reach the goal of 500 MW installed, with an annual power generation of 947.4 GWh [23].

Actually, there are a number of problems hindering the development of renewable sources in Cuba; these include the lack of adequate data on actual energy potential, lack of local capability to manufacture energy equipment and spare parts and lack of both financial support [24].

3.6. The energy policy

In 1993, the National Assembly approved the National Energy Sources Development Program. This document described directions of energy sector development; the objective of this policy was to achieve the maxima efficiency, save energy and use of national energy sources [12]. Today, taking into account the trends of the energy development in Cuba, during the last years and the Energy Revolution programs [25], the actual energy policy addresses the following needs: (1) to meet demand using domestic energy resources as the highest priority, (2) to develop existing sources while acceleration the penetration of new and renewable sources, (3) to diversify energy sources and to avoid dependence on energy imports from a single source or country, (4) to improve energy efficiency in end use and transformation through reduction of losses in energy production, transmission and consumption, (5) gradual introduction of distributed electricity generation and (6) to protect the environment and public health.

4. Overview of the environment situation

4.1. Environmental policy

Protection of the environment and the rational use of natural resources have been a common heritage of Cuban society.

The first National Environmental Strategy (NES) was adopted in 1997, and represented the results of efforts that were spearheaded by the Ministry of Science, Technology and the Environment (CITMA), which was created in 1994 as the lead agency for the activity, together with a number of other Cuban institutions and bodies that are involved in the economic and social development of the country.

At present, the environmental policy and management in Cuba are based on the National Environmental Strategy 2007–2010, approved in 2007, this is supplemented by the National Biodiversity Strategy; the National Strategy for Environmental Education; the National Action Program against Desertification and Drought; and the National Strategy for Biological Safety. Other instruments include the 1997 Environment Act; the sectoral strategies of the Organizations of the State Central Administration (OSCA) of the period 1997–1998; and the Territorial Strategies of the same period [26].

Within the framework of the integrated management of natural resources there are: the Mountain Ecosystems which are special regions for sustainable development; the Hydrographic Basins; the National Council of Hydrographic Basins constituted in 1997 and contains Provincial Councils; the National and Provincial Groups for Bays and Harbours, directed towards integrated management; and the Beaches, Swamps and Protected Areas which fall within a National System, resulting from a Global Environment Facility (GEF/UNDP) project which has been continued under another project entitled: Strengthening of the National System of Protected Areas, which will preserve many representative associations of four eco-regions of the country that will enjoy world wide recognition.

4.2. Environmental problems

The main environmental problems identified in the National Environmental Strategy 2007–2010 are: soil degradation, deforestation, pollution, loss of biological diversity and lack of water.

4.2.1. Soil degradation

The agricultural surface of the country is around of 6.65 million hectares, which represent approximately 60% of the total area of Cuba and the cultivated surface constitute around 54% of the agricultural surface. Soil degradation in Cuba is associated with diverse phenomena such as erosion (2.5 million hectares); poor drainage (2.7 million hectares); salinity (approximately 1 million hectares); acidity (3.4 million hectares); and compaction (approximately 2.5 million hectares), among others.

This situation results in some 60% of the surface of the country being affected by these and other factors which accelerate the processes of desertification.

Among the measures which have been adopted are those embodied in the National Programme for Reforestation; the National Programme to Combat Desertification and Drought; and the National Environmental Strategy. Due to economical limitation, the majority of the mitigation work has been very simple, given the gradual recovery of the forest cover.

4.2.2. Deforestation

The reforestation effort carried out after 1959, received wide support from the population and led to an increase in the forest cover to 127,500 ha during the period 1999–2001, at an approximate rate of 30,000 ha per year. Total forest cover currently stands at 24.5%, as against a potential level of 28%. At present, the National Environmental Strategy incorporates actions to address the problem of deforestation and to improve forest management; a combination of educational and legal tools for the infringement of the legislation in force; support for forest restoration in mountainous areas and fragile ecosystems; and provisions for an increase in the volume of forests for power generation.

4.2.3. Pollution

In Cuba, the pollution of the water, land and atmosphere is due to different causes such as the concentration of industrial installations in urban zones; the uses of obsolete technologies; a low introduction level of cleaner production practices in industries and services. At present, the National Environmental Strategy incorporates actions in order to prevent, reduce and to control the pollution such as the introduction of cleaner production in more than 27 industries, increase the level of recycling of solid and liquid waste, and monitoring of discharges, emission and pollution charges and others. The recycling of waste, both from industry and from the population at large, is among the elements of the waste-management process that require additional organization and financial resources.

4.2.4. Loss of biological diversity

Cuba has adopted a National Biodiversity Strategy and Action Plan, the main activities of this strategy that are currently being implemented are the development of programs for the management and restoration of Hydrographic Basins; the strengthening of the National System of Protected Areas; the rehabilitation of biodiversity in degraded areas; the strengthening of air, water (marine and coastal) and soil pollution controls.

Areas identified for priority attention include the preservation of germoplasm banks; the regulation and control of risks from the use of genetically modified organisms; and special programs for the conservation of species in danger of extinction.

4.2.5. Lack of water

As a result of a large program for the construction of dams, including micro dams, the water storage capacity of the country increased from 48 million cubic meters in 1958, to more than 9600 million cubic meters at the beginning of the present decade. This has permitted a substantial increase in the safe water coverage for the population until 95.6% and a per capita of 1220 m^3 per person per year, but insufficient results to cover residential, agricultural and industrial needs, due to different phenomena such as a prolonged dry periods, water overexploitation, pollution, saline intrusion, deficit of the forest cover and lack of reuse and recycling

of water. The solution of these problems requires significant levels of investment in environmental sanitation in human settlements.

The majority of these activities enjoy the support of the National Program of the Environmental, the Global Environmental Facility (GEF), the United Nations Environmental Programme (UNEP) and the United Nations Development Programme (UNDP).

5. Concluding remarks

Cuba has achieved, since 1959, a considerable progress in the fields of energy, environmental protection and socio economic development which has allowed the attainment of a sustainable development, according to the World Wildlife Fund Report in 2006, this mean that Cuba covers their present needs without compromising the ability of future generations to meet their own needs.

The integration of Cuban society reflects a number of factors, among them, the existence of equal opportunities and access to employment, income and basic services, as well as the strictest respect for diversity, thus eliminating all kinds of discrimination, whether on the basis of gender, ethnicity, religion or social class; and preserving the right to life.

The energy sector has been evolving constantly doing the main results, the distribution of electricity to 97% of the country, the Energy Revolution Programs, in 2006, which has permitted the introduction of the distributed generation of electricity, reaching 40% on the generation in Cuba and the second country with the highest proportions in the world, rehabilitation of the electric grid, substitution of inefficient electric appliances and rapid introduction of renewable energy technologies.

Presently, the soil degradation, deforestation, pollution, loss of biological diversity and lack of water have been identified as the main environmental problems and several plans, projects and policy have been implemented, in order to reduce their impact, following the policy expressed in the National Environmental Strategy.

Finally, challenges exist for the future development of Cuba in the coming years, from an economical point of view will be necessary the enhancement of the economic relations with the American and European countries, to solve internal problems such as insufficient productivity, correspondence between the level of activities with the financial, material and human resources, to promote growth in the levels of exports and to achieve the substitution of imported basic food; the energy sector need to achieve growth in the levels of prospection and exploitation of domestic oil, to diversify fossil energy and energetic technologies suppliers, energy efficiency and the use of renewable energy; the protection of the environment will demand to develop research about adaptation and mitigation of climate change, conservation and rational use of natural resources, in particular, the lands, water and forests.

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